Total Maximum Daily Load

for Sediment and Turbidity in the Waters of

Granite Creek

near Sitka, Alaska

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October 27, 2015
REVISED DRAFT
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1. Overview

Granite Creek was added to the 1996 Clean Water Act (CWA) Section 303(d) list for turbidity and sediment using best professional judgment and visual turbidity observations. Pollutant sources were stormwater runoff from the gravel lease operations, material stockpiles, and road maintenance.

Section 303(d)(1)(C) of the CWA requires a Total Maximum Daily Load (TMDL) for achieving water quality standards when a waterbody is water quality-limited (impaired). The TMDL identifies the pollutant reductions and controls needed to meet water quality standards. If the load allocation needs to be revised (as is the case for Granite Creek), the TMDL also requires revision.

The TMDL approved by Environmental Protection Agency (EPA) in September 2002 established a sediment load and turbidity target. The TMDL was developed using data from five water quality assessments (October 1996, April 1997, December 2000, and October and November 2001). The 2015 TMDL Revision, uses 12 years of data (2002-2013) and calculates new load capacities and turbidity limits.

Table 1. TMDL Revision Summary

TMDL at a Glance:	**2002 TMDL:**	**TMDL Revision:**
Water quality-limited?	Yes	No[1]
Hydrologic unit code (HUC)	190102121206	No change
Assessment unit ID	AK-10203-005 (Lat 57° 06'N; Long -135° 23'W)	No change
Standards of concern	Suspended sediment and turbidity	No change
Designated uses affected	Growth and propagation of fish, shellfish, other aquatic life and wildlife; recreation	No change
Environmental indicators	Total suspended solids (TSS) and turbidity	No change
Major sources	Gravel mining, material stockpiling, roads, recreation, and industrial stormwater runoff	No change
Natural conditions turbidity target	6.64 NTU	5.86 to 8.23 NTUs (varies monthly)
Load capacity	122.00 tons TSS/year; 2.50 to 24.49 tons TSS/month (varies monthly)	170.49 tons TSS/year; 4.56 to 35.44 tons TSS/month (varies monthly)

[1] Pending EPA approval

TMDL at a Glance:	**2002 TMDL:**	**TMDL Revision:**
Existing source load allocation (LA)	140.85 tons TSS/year	63.91 tons TSS/year
Wasteload allocation (WLA)	See below	Stormwater discharges for industrial activity under APDES Multi-Sector General Permit; total of 40.58 TSS/year
Future source load allocation	15.82 tons TSS/year to 22.25 tons TSS/year reserved for LA and/or WLA	61 tons TSS/year reserved for future point and nonpoint sources, potential new sources
Margin of safety	Implicit; series of conservative assumptions	Implicit and Explicit; conservative assumptions; 5 percent[2]; 5 TSS tons/year
Waterbody assessments used for TMDL allocations	October 1996; April 1997; December 2000; October 2001; and November 2001	Monthly August 2002 through June 2013
Proposed future actions	Improve collection and treatment of industrial stormwater runoff; strengthen lease agreements and conduct annual audits; reroute some drainage away from Granite Creek; establish functional vegetated buffers; implement a long-term water quality monitoring program; complete required stormwater control plans; and explore opportunities for fisheries enhancement	Operate, maintain, and monitor BMPs and active management of resource extraction activities through APDES Multi-Sector Permits
Requested Actions		(1) Revise TSS load capacity from 122.00 to 170.49 tons TSS/year based on additional water quality data. (2) Revise existing source load allocation (LA) TSS load from 140.85 to 63.91 tons TSS/year based on additional water quality data. (3) Establish WLA as a weighted average of leased area for individual permits; compliance monitoring required.

[2] 4.7 percent was used for load calculation simplicity.

2. Site background

The Granite Creek Watershed is located within the City and Borough of Sitka, Alaska, four miles north of the downtown area on Halibut Point Road. The watershed is relatively small, encompassing roughly 2.2 square miles or 1,460 acres. Industrial gravel lease sites, roads, recreation areas, and residential/light commercial areas occupies 8% of the watershed. The remainder is muskeg and spruce-hemlock forested wetlands.

Granite Creek has two major tributaries, the North Fork and the South Fork, that converge into the creek main-stem, then continue through the gravel lease sites and the Alaska Department of Natural Resources (DNR) Halibut Point Recreation Area discharging into Sitka Sound. Granite Creek and its tributaries are classified as anadromous (Alaska Department of Fish and Game (ADF&G) catalog number 113-41-10170), supporting Coho salmon, pink salmon and Dolly Varden trout. See Figure 1 for the Granite Creek location map.

3. Applicable Water Quality Criteria

Historically, Granite Creek did not fully support its designated uses due to turbidity and sediment in the water column. Water quality criteria for all designated uses are applicable. Tables 2 and 3 show the water quality criteria for turbidity and sediment on which the original Clean Water Act Section 303(d) listing and TMDL are based.

Table 2. Alaska fresh water quality criteria for turbidity in 18 AAC 70.020(b)(12)

Designated use	Description of criteria
(12)TURBIDITY, FOR FRESH WATER USES (criteria not applicable to groundwater)	
(A) Water supply	
(i) Drinking, culinary, and food processing	May not exceed 5 nephelometric turbidity units (NTU) above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10% increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 25 NTU.
(ii) Agriculture, including irrigation and stock watering	May not cause detrimental effects on indicated use.
(iii) Aquaculture	May not exceed 25 NTU above natural conditions. For all lake waters, may not exceed 5 NTU above natural conditions.
(iv) Industrial	May not cause detrimental effects on established water supply treatment levels.
(B) Water recreation	
(i) Contact recreation	May not exceed 5 NTU above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10% increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 15 NTU. May not exceed 5 NTU above natural turbidity for all lake waters.
(ii) Secondary recreation	May not exceed 10 NTU above natural conditions when natural turbidity is 50 NTU or less, and may not have more than 20% increase in turbidity when the natural turbidity is greater than 50 NTU, not to exceed a maximum increase of 15 NTU. For all lake waters, turbidity may not exceed 5 NTU above natural turbidity.
(C) Growth and propagation of fish, shellfish, other aquatic life, and wildlife	Same as (12)(A)(iii).

Source: 18 AAC 70.020 (ADEC 2012)

Table 3. Alaska fresh water quality criteria for sediment in 18 AAC 70.020(b)(9)

Designated use	Description of criteria
(9) SEDIMENT, FOR FRESH WATER USES (criteria not applicable to groundwater)	
(A) Water supply	
(i) Drinking, culinary, and food processing	No measurable increase in concentration of settleable solids above natural conditions as measured by the volumetric Imhoff cone method (see note 11).
(ii) Agriculture, including irrigation and stock watering	For sprinkler irrigation, water must be free of particles of 0.074 mm or coarser. For irrigation or water spreading, may not exceed 200 mg/l for an extended period of time.
(iv) Industrial	Same as (9)(A)(iii).
(B) Water recreation	
(i) Contact recreation	Same as (A) (i).
(ii) Secondary recreation	May not pose hazards to incidental human contact or cause interference with the use.
(C) Growth and propagation of fish, shellfish, other aquatic life, and wildlife	The percent accumulation of fine sediment in the range of 0.1 mm to 4.0 mm in the gravel bed of waters used by anadromous or resident fish for spawning may not be increased more than 5% by weight above natural conditions (as shown from grain size accumulation graph). In no case may the 0.1 mm to 4.0 mm fine sediment range in those gravel beds exceed a maximum of 30% by weight (as shown from grain size accumulation graph) (see notes 3 and 4). In all other surface waters no sediment loads (suspended or deposited) that can cause adverse effects on aquatic animal or plant life, their reproduction or habitat may be present.

3. Wherever criteria for fine sediments are provided in this chapter, fine sediments must be sampled by the method described in *An Improved Technique for Freeze Sampling Streambed Sediments*, by William J. Walkotten, United States Department of Agriculture, United States Forest Service, Forest Service Research Note PNW-281, October 1976, adopted by reference, or by the technique found in *Success of Pink Salmon Spawning Relative to Size of Spawning Bed Materials*, by William J. McNeil and W.H. Ahnell, United States Department of the Interior, United States Fish and Wildlife Service, Special Scientific Report - Fisheries No. 469, January 1964, pages 1 - 3, adopted by reference.

4. Wherever criteria for fine sediments are provided in this chapter, percent accumulation of fine sediments will be measured by the technique found in the *Manual on Test Sieving Methods*, *Guidelines for Establishing Sieve Analysis Procedures*, by the American Society for Testing and Materials (ASTM), STP 447A, 1972 edition.

11. Volumetric measurements of settleable solids must be determined according to the following

procedure:

(A) first, an Imhoff cone must be filled to the one-liter mark with thoroughly mixed sample;
(B) second, the sample must settle for 45 minutes;
(C) third, the sides of the cone must be gently stirred with a rod or by spinning;
(D) fourth, the sample must settle 15 minutes longer, and the volume of settleable matter in the cone must be recorded as milliliters per liter;
(E) fifth, if the settled matter contains pockets of liquid between large settled particles, the volume of these pockets must be estimated and subtracted from the volume of settled matter.

Source: 18 AAC 70.020 (ADEC 2012)

Figure 1. Granite Creek location map

4. TMDL background

Granite Creek was added to the 1996 CWA Section 303(d) list for turbidity and sediment. Pollutant sources were stormwater runoff from the gravel lease operations, material stockpiles, and road maintenance. A TMDL was prepared to improve water quality and was approved by the EPA in September 2002. Figure 2 shows the Granite Creek and the surrounding area.

Figure 2. Granite Creek and surrounding area

5. 2002 TMDL summary

The 2002 TMDL used total suspended solids (TSS) as a surrogate to establish the necessary water quality improvement goals that address both the turbidity and the sediment impairments. The TSS surrogate is necessary, because turbidity is an optical property and is a measure of the amount of light-scattering particles in the water. Since load capacities are expressed as a mass per unit time, the turbidity measurements could not be used directly to calculate sediment loads or load allocations. A site specific conversion of turbidity values to equivalent TSS values is used to estimate sediment loads gravimetrically (by weight, in tons) that are then converted into load allocations in the TMDL.

Water quality issues associated with turbidity are typically linked to sediment loading from watershed sources. Historical water quality data collected in the watershed was almost exclusively for turbidity. Because of the lack of available data to characterize sediment characteristics, coupled with the fact that criteria for sediment that are not easily converted to load allocations, the numeric turbidity criteria listed above were selected as an appropriate indicator to assure attainment of sediment standards in the TMDL. As described previously, turbidity measurements were converted to gravimetric (weight based) TSS values for purposes of sediment load calculations.

In the 2002 TMDL, the initial data used to calculate sediment load was limited. Water quality data for several months of the year was not collected; specifically during winter and early summer months. The relationship between turbidity and TSS was based on two options.

1. Concurrent TSS and turbidity measurements were made at ten stations in October and November 2001. The ratio of turbidity/TSS was calculated, regression analysis ran on the data sets, and a regression equation was generated. This direct linear relationship was applied to convert turbidity (optical) data to TSS (mg/L).

2. The correlation presented in Lloyd et al (1987) for interior Alaskan streams was applied to the turbidity data. The results were compared to the regression analysis. Equation details can be found in the 2002 TMDL document.

The annual source load capacity and existing in-stream TSS load were estimated as 122.00 and 140.85 tons TSS/year, respectively in the 2002 TMDL. Future wasteload allocation (permitted point sources) and load allocations (unpermitted non-point sources) were combined and were calculated as 15.82 tons TSS/year (Option 2) to 22.25 tons TSS/year (Option 1). Option 1 involved rerouting the ditchwater/drainage from the golf course and existing overburden waste site directly into Sitka Sound. The 2002 TMDL load allocations are shown on Table 4.

Table 4. 2002 TMDL allocations

Month	Existing TSS load (tons)	TSS load capacity (tons)	Required reduction in existing load (% / tons)	Load allocation (tons) Option 1	Load allocation (tons) Option 2
Total annual tons	**140.85**	**122.00**	**41.10**	**99.75**[3]	**106.18**[4]
Jan	8.78	9.59	0 / 0	8.78	8.78
Feb	0.05	2.50	0 / 0	0.46	**1.50**
Mar	0.78	4.28	0 / 0	0.78	0.78
Apr	10.43	8.14	22 / 2.29	8.14	8.14
May	14.16	11.05	22 / 3.11	11.05	11.05
Jun	9.70	10.59	0 / 0	9.70	9.70
Jul	1.24	6.78	0 / 0	1.24	**2.75**
Aug	1.01	5.53	0 / 0	1.01	**3.00**
Sep	24.82	16.94	32 / 7.88	16.94	16.94
Oct	44.85	24.49	45 / 20.02	24.49	24.49
Nov	1.11	6.06	0 / 0	1.11	**3.00**
Dec	23.51	16.05	31 / 7.46	16.05	16.05

[3] Represents load allocation for existing sources. 122.00 – 99.75 = up to 22.25 tons TSS are reserved for allocation among future nonpoint and point sources.
[4] Represents alternative load allocation where 6.43 tons of TSS will be taken from the future allocation, bringing the existing source load allocation to 106.18 tons TSS/year (99.75 tons + 6.43 tons) and reducing future LA/WLAs to 15.82 tons TSS/year. This extra allocation is made available from 4 of the 7 months where there is an excess load capacity (load capacity exceeds existing TSS loads). These 4 months are shown in **bold** in the last column.

6. Actions completed since 2002 TMDL

Over 25 different tasks were implemented as a result of the TMDL to help ensure attainment of turbidity and sediment standards in the waterbody. These tasks implemented best management practices (BMPs) throughout the watershed. Tasks included the following:

- construction of a series of settling ponds
- protection and expansion of streamside vegetated riparian buffers
- hydroseeding of erodible soils
- placement of physical barriers to limit encroachment on stream banks
- culvert and drainage improvements
- routine grading of roads and paving segments
- education of operators
- semi-annual environmental audits to document inspection findings and recommend needed corrective actions

Water quality monitoring was conducted to evaluate the effectiveness of the tasks. By 2009, significant improvements were consistently shown in water quality. Following the improvements, there were three isolated turbidity exceedances above the monthly background turbidity targets (November 2009, October 2010, and February 2013). The exceedances were associated with high stream flow, and natural turbid conditions. During low flow conditions, no turbidity exceedences have occurred since the improvements.

Figure 3 shows implemented BMPs; further details are described in the Storm Water Pollution Prevention Plan, Multi-sector General Permits and annual reports, and supporting documents found at the DEC Division of Water, Water Permit Database Search http://dec.alaska.gov/Applications/Water/WaterPermitSearch/Search.aspx.

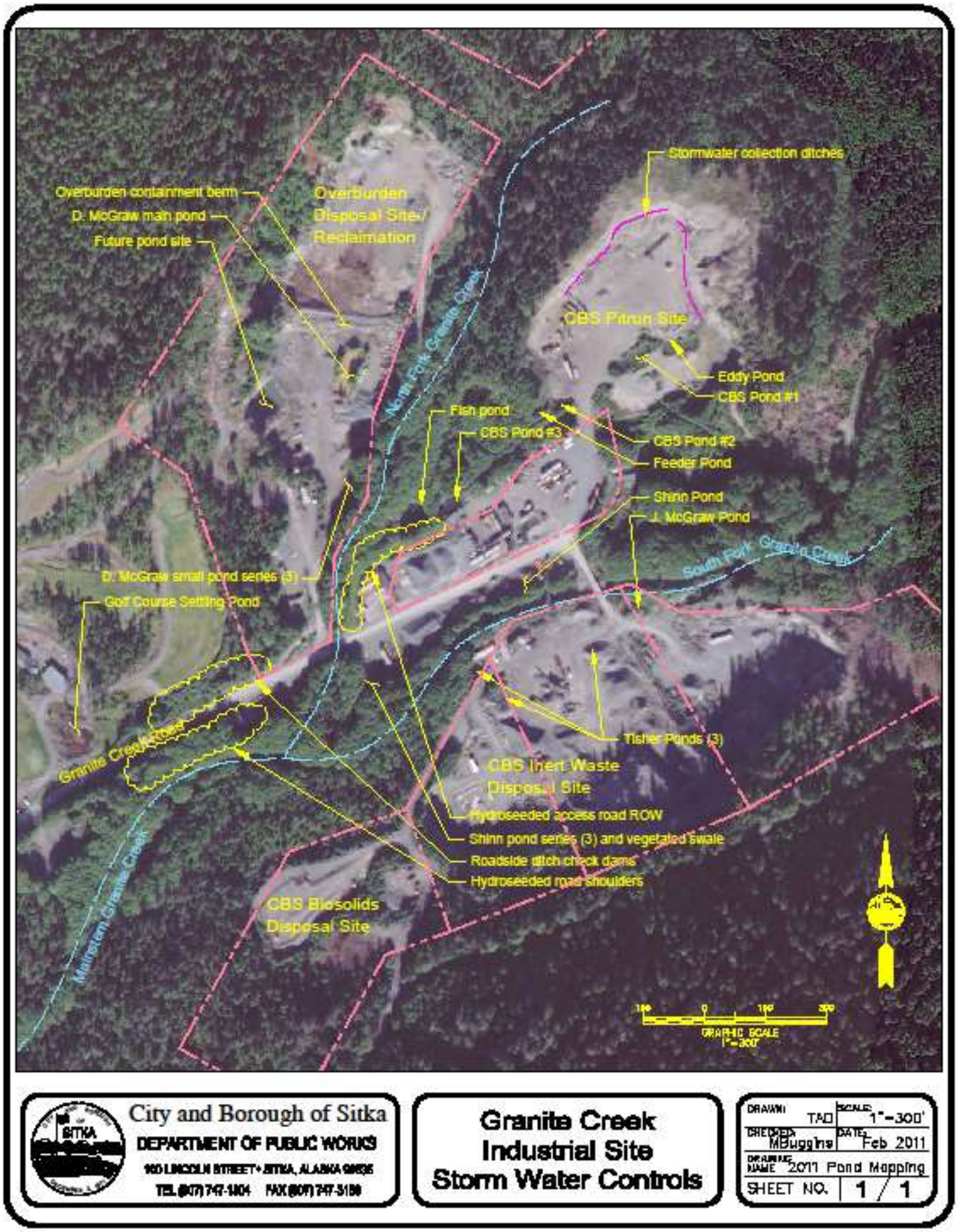

Figure 3: Structural BMPs and stormwater controls in Granite Creek industrial area

7. 2002 – 2013 Data collection

Prior to 2002, no flow data is available for Granite Creek. The lack of data resulted in the 2002 TMDL using flow assumptions that underestimated actual seasonal flow during several months, and overestimated flow in other months. In 2002, a permanent staff gage was installed by the U.S. Geological Survey (USGS). In addition, turbidity and TSS sampling was conducted.

Figure 4 shows Granite Creek sampling locations. The City and Borough of Sitka Department of Public Works, including the department staff and a contractor funded through Alaska Clean Water Actions (ACWA) grants, collected monitoring data from 2002 to 2013. From 2002 – 2007, the sampling program selectively targeted high flow events. From 2007 – 2013, the sampling program was collected creek data representative of all weather conditions to avoid selectively targeting high flow events and biasing the resultant data.

GC1 is located near the mouth of the stream, and captures runoff and sediment/turbidity leaving the Granite Creek project area (Figure 2). GC1 is near the USGS staff gage.

GC2 is situated upstream of GC1, immediately downstream of the gravel operations.

GC3, GC4 and North Fork control sample locations represent background conditions, and are located above all gravel mining operations or other activities. The natural conditions turbidity target was calculated from data collected from 2002 to 2010, and varies monthly from 5.86 to 8.23 NTUs (see Table 5). The 2002 TMDL also used data from these sites to establish the TMDL targets. Appendix A provides all of the data collected.

Figure 4: Granite Creek sampling locations

7.1. Average monthly flow.

Station GC1 turbidity and TSS data were collected from 2002 through 2013. Stream gage height was recorded, and converted to flow rate (cfs) using the Granite Creek USGS stream rating table.

The average monthly flow rates were recalculated using the entire data set.[5] Average monthly flow rates are shown in Table 5 and Appendix A.

7.2. Turbidity and TSS levels.

Turbidity and TSS levels were collected at all five of the sample sites. Appendix A provides all of the data collected.

When GC1 exceeded the monthly background turbidity value of 6.64 NTU established in the 2002 TMDL, efforts were made to sample the upstream sites; unfortunately, upstream sampling did not always occur. The months of January, February, July, August and December have no background turbidity data from 2002-2013; therefore the 2002 TMDL target of 6.64 NTU (based on a natural background a natural background turbidity of 1.64 NTU) was used for these months.

[5] No flow rate data is available from September 2006 through February 2007 when the staff gage was damaged. USGS repaired and resurveyed the gage in February 2007. No flow rate data is available from September 2012 to July 2014 when the gage was damaged. USGS has no plans to repair or resurvey the staff gage.

Table 5: Revised TMDL allocations

Month	Average monthly flow (cfs)	Monthly natural background turbidity (NTU)	Target background turbidity (NTU)	Target TSS[6] (mg/L)	Average monthly TSS (mg/L)[7]	Existing TSS load (tons)[8]	TSS Load capacity (tons)[9]	TSS remaining capacity (tons)[10]
Total annual						63.91 (109.66)[11]	170.49 (228.52)	106.58 (118.86)
Jan	34.71	1.64[12]	6.64	6.08	2.20	6.39	17.65	11.26
Feb	20.59	1.64	6.64	6.08	1.55	2.41	9.46	7.05
Mar	15.45	0.86	5.86	5.20	1.28	1.66	6.73	5.07
Apr	9.63	1.43	6.43	5.84	0.93	0.73	4.56	3.83
May	16.78	1.63	6.63	6.07	1.35	1.90	8.52	6.62
Jun	10.01	1.46	6.46	5.88	0.96	0.78	4.76	3.99
Jul	9.02	1.64	6.64	6.08	0.89	0.67	4.59	3.92
Aug	34.97	1.64	6.64	6.08	2.21	6.47	17.79	11.32
Sep	52.66	3.23	8.23	7.86	2.91	12.41	33.52	21.10
Oct	26.51	2.65	7.65	7.21	1.84	4.08	15.99	11.91
Nov	77.72 (103.05)[13]	1.24	6.24	5.63	3.70 (4.56)	23.29 (38.04)	35.44 (46.98)	12.14 (8.94)
Dec	22.58 (71.93)[14]	1.64	6.64	6.08	1.65 (3.58)	3.12 (21.57)	11.48 (36.59)	8.37 (15.02)

[6] Target TSS (mg/L) = [1.12 (monthly average natural turbidity in NTUs)] – 1.36
[7] Average monthly TSS using Log (TSS (mg/L)) = 0.67 * log (average monthly flow (cfs)) - 0.69)
[8] Existing TSS load = monthly average flow (cfs) *0.0027 * average monthly TSS (mg/l) * # days in the month
[9] TSS load capacity = average monthly flow (cfs) * 0.0027 * Target TSS * # days in the month
[10] Remaining capacity = load capacity – existing load
[11] Values in ( ) are calculated including the highest recorded flow outlier.
[12] Background turbidity data from 2002-2013 not available for Jan, Feb, Jul, Aug and Dec; used 2002 TMDL avg. of 6.64.
[13] November average monthly flow calculated with highest recorded outlier flow (1,390 cfs in 2005) included. Additional flow measurements were collected in November to have a statistically accurate assessment.
[14] December average monthly flow calculated with highest recorded outlier flow (1,070 cfs in 2004) included.

8. 2002 – 2013 Data analysis

Alaska Department of Environmental Conservation (ADEC) used the same process as during the 2002 TMDL development to analyze all the 2002-2013 water quality data. The revised TMDL allocations are shown on Table 6.

8.1. Removal of flow outliers.

Using a conservative approach, flow measurements were analyzed and outliers were removed. The analysis resulted in one data point being removed for both November and December data. Table 5 presents the both the adjusted and unadjusted values.

Between Novembers 2006-2012, flows exceeded 58.3 cfs one time (101 cfs in November 2010). The high flows of 1,390 cfs in November 2005, and 863 cfs in November 2003 have skewed the average monthly flow artificially high. Excluding one or both of these high flows significantly lowers the existing TSS load. As a conservative approach (and included in the margin of safety) only the highest flow (1,390 cfs) was excluded from the analysis. A similar analysis resulting in the removal of extreme outliers was conducted for December flow rates.

The rationale for removing extreme "outlier" data points was further explored with the USGS to confirm that the practice is supported in calculations of average monthly flow to avoid high bias when relatively few data points are available. USGS confirmed that, in cases where stage discharge curve is based on relatively few high flow measurements, and when the estimated flow rate using the stage discharge curve is greater than twice the highest directly measured stream flow, that the estimated flow rate is suspect. The flow of 1,390 cfs estimated in November 2005 was 15 times higher than the 90.2 cfs maximum measured flow rate that was used to develop the stage discharge curve for Granite Creek. It is accepted practice by professional hydrologists to question such flows as no calibration flows exist. This information further supports removing both December 2004 (1,070 cfs) and November 2005 (1,390 cfs) values from average monthly flow calculations.

8.2. Turbidity levels.

The most stringent turbidity criteria are for drinking water use (see Table 2) states that turbidity may not exceed 5 NTUs above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10% increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 25 NTU. The average natural background turbidity levels in Granite Creek are shown by month in Table 5.

Because improvements in operational practices occurred over time, with most of the improvements occurring prior to 2006, the most current data was used to determine whether water quality criteria for turbidity are being met. Measurements taken at GC2 were evaluated to determine whether impacts seen at GC1 originated from gravel mining operations or could result from other sources (both anthropogenic and non-anthropogenic).

When GC1 exceeded the monthly background turbidity value of 6.64 NTU established in the 2002 TMDL, efforts were made to sample the upstream sites. Upstream sample site GC2 showed elevated turbidity values in October 2006, May and October 2007, and September and October 2008. Tables 5 and 6 note the monthly target background turbidity levels. Out of the 485 turbidity samples collected, only 37 samples had exceedences. Turbidity exceedences for all sampling locations are shown on Table 6.

Of the 46 turbidity measurements recorded at GC1 from January 2010 – June 2013, only the October 2010 and February 2013 storm events (4.3%) were above the turbidity target during high flow conditions. The October 2010 storm event consisted of 2.18 inches of rain in the 24 hours prior to sampling. The February 20, 2013 storm event, consisting of heavy rain falling on a significant snow pack, resulted in excessive melting and flooding. Other high flow events during this 3.5 year timeframe from all of the sampling locations did not show exceedances.

Table 6: Turbidity exceedences (NTU)

Month	Year	GC1	GC2	GC3	GC4	Target background turbidity
Jan	2005	19.9				6.64
	2006	9.39				
Feb	2004	6.81				6.64
	2005	9.12				
	2006	9.9				
	2013	9.78				
Mar	2008	18.1				5.86
May	2006	8.55				6.63
	2007		24.05			
Aug	2005	8.11				6.64
	2006	9.97				
	2007	23.9		-		
Sep	2003	16.5				8.23
	2005	16.2				
	2006	13.5				
	2008	14.6, 40.1, 8.9	23.05			
Oct	2002	44.85			14.8	7.65
	2004			12.3		
	2006	20.2, 52.45	96.4			
	2007	10.12, 15.4	18.45			
	2010	10.3				
Nov	2002	17.4				6.24
	2005	19.4				
	2009	6.4, 12.7, 7.72				
Dec	2003	7.28				6.64
	2004	95				
	2007	8.12				

8.3. Sediment (TSS)-to-turbidity relationship.

Water quality measurements of TSS and turbidity were collected for analyses from 2002 - 2013. Turbidity is an optical property and is a measure of the amount of light-scattering particles in the water. Since load capacities are expressed as a mass per unit time, the turbidity measurements could not be used directly to calculate sediment loads or load allocations. A conversion of turbidity values to an equivalent TSS value to estimate sediment loads gravimetrically (by weight, in tons) was necessary. A linear regression analysis for sediment (TSS)-to-turbidity relationship was performed on the entire data set (217 data points). The equation for the target TSS concentration generated is shown below. The monthly target TSS is shown on Table 5.

TSS (mg/L) = [1.12 (monthly average natural turbidity in NTUs)] – 1.36

The linear equation representing the regression/line of Best Fit is $y = m \times x + b$, where:

- y variable is TSS
- x variable is turbidity
- slope is $m = 1.12$
- b intercept on the graph is $b = -1.36$

For example, January has an average monthly turbidity of 6.64 NTUs. Using the equation: (1.12) (6.64) – 1.36 = 6.08. This represents the target TSS concentration for January during the period October 2002 through June 2013.

8.4. Sediment (TSS)-to-flow relationship.

The most common statistical method of analyzing sediment – discharge data is a power function (regression analysis) that relates TSS to flow rate. A common logarithmic transformation of both TSS and discharge data is done prior to analysis. Logarithmic transformation makes it easier to evaluate the relationship between two variables by linearizing the relationship, normalizing distribution of highly skewed data, and stabilizing variance. By transforming both variables, the log-log association becomes linear when plotted. The USGS used this identical method to plot Granite Creek gage height data and discharge data on a log-log scale, generating the stage-discharge curve for Granite Creek in 2005.

The regression analysis sediment (TSS)-to-flow relationship was completed using all 122 simultaneous TSS-flow rate data sets collected from October 2002 through June 2013. Appendix A includes all simultaneous TSS and flow data collected from October 2002 - June 2013. The following TSS-to-flow rate equation was used for generating the average monthly TSS in Table 5.

Log (TSS (mg/l)) = 0.67 * log (average monthly flow (cfs)) - 0.69

The linear equation representing the regression/line of Best Fit is $y = m \times x + b$, where:

- y variable is TSS
- x variable is flow rate
- slope is $m = 0.67$
- b intercept on the graph is $b = -0.69$

For example, January has an average monthly flow of 34.71 cfs. Log transformation of 34.71 gives a value of 1.54. Using the equation: (0.67) (1.54) - 0.69 = 0.34. The antilogarithm of 0.34 is 2.20 mg/L TSS, which represents the average monthly TSS concentration for January for the period October 2002 through June 2013.

8.5. Existing TSS load.

The monthly and annual existing TSS loads were then calculated using the following equation.

Existing TSS load = average monthly flow (cfs) * 0.0027[15] * average monthly TSS concentration (mg/L) * number of days in the month

For example, January has an average monthly flow of 34.71 cfs, an average TSS concentration of 2.20 mg/L, and has 31 days in the month. Using the equation, the existing TSS load is 6.39 tons. This represents January's existing TSS load in tons using data sets from 2002 - 2013. The annual TSS load capacity is 63.91. Table 5 shows existing TSS loads.

8.6. TSS load capacity.

The monthly and annual TSS load capacity were then calculated using the following equation.

TSS load capacity = average monthly flow (cfs) * 0.0027[16] * Target TSS * # days in the month

For example, January has an average monthly flow of 34.71 cfs, a target TSS concentration of 6.08 mg/L, and has 31 days in the month. Using the equation, the TSS load capacity is 17.65 tons. This represents January's TSS load capacity in tons using data sets from 2002 - 2013. The annual load capacity is 170.49. Table 5 shows the monthly and annual TSS load capacity.

[15] The multiplier 0.0027 converts the result to tons/day.
[16] The multiplier 0.0027 converts the result to tons/day.

8.7. TSS remaining capacity.

The monthly and annual TSS remaining capacity were then calculated using the following equation.

Remaining capacity = load capacity – existing load

For example, January has a load capacity of 17.65 tons, an existing load of 6.39 tons, resulting in an remaining capacity of 11.26 tons. This represents January's TSS assimiliative capacity in tons using data sets from 2002 - 2013. The annual TSS remaining capacity is 106.58. Table 5 shows monthly and annual TSS remaining capacity.

8.8. Margin of safety.

The 2002 TMDL used an implicit margin of safety (MOS) in the source load calculations through a series of conservative assumptions. Based on the expanded water quality data set collected from 2002-2013, these assumptions need to be revised. The margin of safety is included in a TMDL to account for any uncertainty or lack of knowledge regarding the pollutant loads and the response of the receiving water. The MOS can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. This revised TMDL includes both an implicit and explicit MOS.

A 5 percent[17] explicit MOS is used because the expanded water quality data set collected from 2002-2013 is expected to provide accurate information on the loading capacity of the stream, but the estimate could be subject to potential error associated with inherent collection and analytical methods. Conservation assumptions (implicit) included using the entire gravel operation lease area in the wasteload allocations, instead of the current disturbed area, to provide a conservative approach and to ensure consistency throughout the life of the revised TMDL. Another conservative assumption is setting the natural background turbidity at 1.64 NTU for several months (January, February, July, August and December) since was no background turbidity data was collected for these months since the development of 2002 TMDL. A third conservative approach involved only excluding one of the two highest November flow measurements (1,390 cfs) from the analysis.

8.9. Reasonable Assurance.

This is a mixed source TMDL, which comprises both point and nonpoint sources, therefore reasonable assurance is included. Reasonable assurance is necessary to show that the wasteload allocation and load allocation, in combination, are established to provide a high degree of confidence that the goals outlined in the revised TMDL can be achieved.

Available in-stream and analytical data were used to quantify sediment loads to the creek. This approach characterizes the contribution of sediment from both nonpoint sources and point sources

[17] 4.7 percent was used for load calculation simplicity.

(including future point sources) to Granite Creek. Over 25 different tasks and BMPs were accomplished to help ensure attainment of turbidity and sediment standards in the waterbody. Education, outreach, technical assistance, permit administration, and permit enforcement will all be used to ensure that all pollutant sources will continue to meet the wasteload and load allocations.

8.10. Annual TSS load reductions.

Since the annual load capacity of 170.49 tons exceeds the annual existing TSS load of 63.91 tons, no load reductions are necessary on an annual basis. For the 12 months of the year, existing TSS loads are less than the load capacity for that particular month. Therefore, calculated on a monthly basis, no load reductions are necessary.

8.11. Daily load expression.

The load capacity, existing source load allocation (LA), wasteload allocation (WLA), future source load allocation, margin of safety (MOS) are all shown in Table 1 as TSS tons/year. These TSS loads can also be shown as a daily expression; see Table 7 below.

Table 7: Revised TMDL daily allocations

Month	Existing TSS load (tons)[18]	TSS Load capacity (tons)[19]	TSS remaining capacity (tons)[20]
Total daily average	0.18 (0.30)[21]	0.47 (0.63)	0.29 (0.33)
Jan	0.21	0.57	0.36
Feb	0.09	0.34	0.25
Mar	0.05	0.22	0.16
Apr	0.02	0.15	0.13
May	0.06	0.27	0.21
Jun	0.03	0.16	0.13
Jul	0.02	0.15	0.13
Aug	0.21	0.57	0.37
Sep	0.41	1.12	0.70
Oct	0.13	0.52	0.38
Nov	0.78 (1.27)[22]	1.18 (1.57)	0.40 (0.30)
Dec	0.10 (0.70)[23]	0.37 (1.18)	0.27 (0.48)

[18] Existing TSS load = monthly average flow (cfs) *0.0027 * average monthly TSS (mg/l)
[19] TSS load capacity = average monthly flow (cfs) * 0.0027 * Target TSS
[20] Remaining capacity = load capacity – existing load
[21] Values in ( ) are calculated including the highest recorded flow outlier.
[22] November average monthly flow calculated with highest recorded outlier flow (1,390 cfs in 2005) included. Additional flow measurements were collected in November to have a statistically accurate assessment.
[23] December average monthly flow calculated with highest recorded outlier flow (1,070 cfs in 2004) included.

8.12. Wasteload allocations.

The wasteload allocation was determined using a weighted average of the leased area listed in the APDES Multi-Sector General Permits and leased area information provided by the City/Borough of Sitka with no known associated permits. The total leased area covers 15.69 acres. Table 8 and Figure 5 details the leased areas.

Wasteload allocation = (remaining capacity - future load - margin of safety) / leased area

2.59 TSS tons/acre/year = (106.58 TSS tons/year - 61 TSS tons/year - 5 TSS tons/year) / 15.69 leased area

2.59 TSS tons/acre/year = (40.58 TSS tons/year) / 15.69 leased area

The leased area was used in the wasteload allocations, instead of disturbed areas, to provide a conservative approach and have consistency throughout the life of the revised TMDL document. To verify that discharges meet the calculated wasteload allocations and ensure compliance with Section *7.2.3.2 Impaired Waters Monitoring Schedule*, *Discharges to impaired waters with an EPA approved or established TMDL WLA* of the APDES Multi-Sector General Permit for Stormwater Discharges Associated with Industrial Activity, the permittee should contact the Wastewater Discharge Authorization Program for additional sampling requirements.

Alaska Department of Environmental Conservation
Wastewater Discharge Authorization Program
555 Cordova Street
Anchorage, AK 99501

Table 8: Gravel operation data[24]

Leased lot ID	Leased acres	Permit ID	WLA in TSS tons/year
Granite Creek Industrial Area (aka CBS Pit Run Site)	3.5	AKR06AA97 (previous permit AKR05CF21)	9.07
Lease area 4	5.8	AKR05CB21	15.02
Lease area 5	6	AKR05CB69	15.54
Lease area east of Granite Creek Lease Area 7[25], south of CBS Pit Run Site	0.39	No permit application received	1.01

[24] Lease areas 2, 2A, Modification to Site 2 and extended operations on north side is no longer operating; DEC was notified September 18, 2015. These areas are included in the future load allocation.
[25] Lease area 7, a portion of Lot 1 Alaska State Land Survey 3670 is not required to have a MSGP.

Figure 5: Gravel operations lease areas

8.13. Future source load allocation.

The future source (or growth) allocation for sediment from potential new sources coming into the watershed is 61 tons sediment/year including both nonpoint sources and point sources. This allocation includes unknown potential new sources, and the one existing lease area where there is no current operation or lessee; specifically, Lease Areas 2, 2A, and Modification to Site 2. The future load allocation equation is shown below.

Future source allocation = load allocation – margin of safety – wasteload allocation

61 TSS tons/year = 106.58 tons/year – 5 tons/year – 40.58 tons/year

9. Conclusions and future implementation

The 2002 TSS loads were developed based on the best available information at the time. The expanded water quality database collected from 2002-2013 has led to refinements in average monthly flow, and existing TSS load and load capacity, providing a more accurate and statistically valid data set.

By 2009, significant improvements were consistently shown in water quality. Following the improvements, high stream flows activated natural turbid conditions in the waterbody, resulting in isolated turbidity exceedences (November 2009, October 2010, and February 2013). No turbidity exceedences have occurred during low stream flow events since the improvements.

The turbidity data collected over 12 years shows a consistent decrease in turbidity concentrations due to BMP implementation, and no current persistent turbidity impairment in Granite Creek.

The Alaska WQS turbidity criteria and monthly turbidity target levels have been consistently met for 3.5 years (January 2010 through June 2013), with only two exceptions in October 2010 and February 2013 during storm events. Based on the Granite Creek turbidity levels and relationship to sediment, the sediment criteria have also been met.

The revised existing annual TSS load (63.91 tons) is below the annual TSS load capacity (170.49 tons). Improved sediment controls and more accurate water quality data show that existing TSS loads are consistently below TSS load capacity for all 12 months of the year, and the remaining load capacity (106.58 tons) provides an ample buffer.

The implementation of BMPs designed to help ensure attainment of turbidity and sediment standards in Granite Creek have caused the waterbody to meet Alaska Water Quality Standards and TMDL load and wasteload allocations.

10. Public participation

Granite Creek TMDL Revision was placed on Public Notice on November 6, 2015 via DEC website, the Daily Sitka Sentinel and the Juneau Empire.

11. Referenced documents

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